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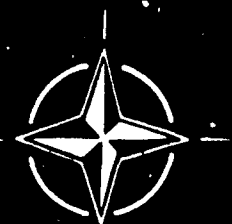
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AGARD Advisory Report No.244

**Technical Evaluation Report  
on the  
Flight Mechanics Panel Symposium on  
Flight Vehicle Development  
Time and Cost Reduction**

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**AGARD Advisory Report No.244**  
**TECHNICAL EVALUATION REPORT**  
**on the**  
**FLIGHT MECHANICS PANEL SYMPOSIUM**  
**on**  
**FLIGHT VEHICLE DEVELOPMENT**  
**TIME AND COST REDUCTION**

by

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**This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.**

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- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
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## PREFACE

There is a current perception that the time and especially the cost of development of new systems are increasing at a rate that is greater than the rate of improvement of the capabilities of the systems. The purpose of this symposium was to provide a forum to identify and discuss the elements that contribute to the increased time and cost of development, and to explore the question of what can be done to arrest and reverse the trend.

Time and cost savings methods emanating from technology advancements were shown to be largely available and in some cases being used. The major benefits of the technology advancements are cost avoidances and schedule improvement resulting from the early identification and resolution of problems. The primary areas to seek further redress of time and cost growth are in the definition of requirements and the decision making processes.

Another aim of this symposium was to encourage others in the nontechnical area to join with the technical people in attacking these problems resolutely. It is considered that the meeting was successful in focusing attention on this situation, showing what technologies can do to reduce development time and cost growth, and by highlighting other key areas that must be addressed to reverse the trend. The final recommendation of the symposium was to make sure that military and government leaders get this message.

The Conference Proceedings, commissioned by the AGARD Flight Mechanics Panel, are published separately as AGARD CP424.

\* \* \*

Il est généralement admis que les délais de fabrication et surtout le coût des nouveaux systèmes ne cessent d'accroître, et ceci selon une courbe exponentielle dont l'évolution dépasse celle des nouvelles capacités des systèmes. Ce symposium a servi de forum pour l'identification et la discussion des éléments constitutifs de cette augmentation des coûts et des délais et pour un examen des solutions qui permettraient d'arrêter cette tendance, voire même la renverser.

Des méthodes découlant des progrès technologiques réalisés récemment, qui permettent de réduire les délais et de réaliser des économies sont déjà définies et sont appliquées dans certains cas. Les principaux avantages qui en résultent résident dans l'évitement de dépenses et le respect des dates inscrites aux plannings grâce à l'identification précoce des problèmes et leur résolution en temps voulu. Les deux domaines principaux où le redressement de l'augmentation des délais et des coûts est envisageable seraient la définition des besoins et le processus de prise de décision.

L'un des objectifs de ce symposium fut d'encourager les différents partenaires non-techniques à se joindre au techniciens afin d'attaquer ces problèmes avec détermination. La réunion a réussi à attirer l'attention des participants sur la situation actuelle, en démontrant le potentiel des nouvelles technologies en ce qui concerne la réduction des coûts et des délais et en soulignant d'autres questions clés qui devront être abordées afin de renverser cette tendance à la hausse.

Enfin, les participants au symposium se sont déclarés unanimes en souhaitant que ce message soit transmis aux décideurs militaires et gouvernementaux.

Le compte rendu de la conférence, demandé par le Panel AGARD de la Mécanique du Vol, est édité séparément sous la référence AGARD CP 424.



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## FLIGHT VEHICLE DEVELOPMENT TIME AND COST REDUCTION

### INTRODUCTION

An AGARD Flight Mechanics Panel symposium on Flight Vehicle Development Time and Cost Reduction was held in Toulouse, France, May 11-14, 1987. The purpose of the symposium was to discuss the large increases in development time and cost which have become apparent in recent years, and to explore possible means of arresting the growth.

As an activity of an AGARD technical panel, the symposium directed much of its attention to the technical aspects of the question, with emphasis on technical trends which may have worsened the problem or which may represent hope for improvement. The technical presentations did in fact address a number of technology advances, some already in use, which have the potential for reducing development time and cost. In most instances, however, these innovations are being applied to achieve improved system performance or to offset the additional costs of increasing performance or other program requirements. Technical advances which offer potential economy benefits such as weight reduction or computational cost reduction, for example, are almost always applied instead to achieve alternative required advantages such as increased payload or greater computational capability.

Symposium participants also included individuals involved in the management of major military system development programs, and the discussions brought out a number of non-technical issues of importance to the military customer. In the consensus view of the symposium attendees, the management and programmatic issues overshadowed the technology from the standpoint of potential for achieving significant development time and cost reductions.

This Technical Evaluation Report does not attempt to summarize or assess the individual papers which were presented at the symposium and which are listed as references 1 through 29. Rather, it summarizes the overall situation as portrayed by the sum of the papers, the symposium discussions, relevant reference material, and recent studies.

### INCREASES IN DEVELOPMENT TIME AND COST

The seriousness of the development time and cost increases was clearly depicted in the keynote and general overview papers (e.g. references 1, 2, and 7). Data presented, for example, showed that the unit flyaway cost of a typical 1980's tactical aircraft in constant dollars (i.e. adjusted for inflation) has more than tripled with respect to a typical 1960's tactical aircraft. Other studies showing similar trends indicate a seven percent per year compound growth as a representative average figure, with a number of extreme cases showing much more than the threefold increase.

The data also show fifty-to one hundred-percent increases in total development time during the same twenty-year period. Some systems today require twelve to fifteen years for development in comparison with the five-or six-year developments of the 1960's.

Although these trends are not unique to combat aircraft, the increases — and the projections of continuing increases, have obvious serious impacts in terms of quantities of combat aircraft that can be purchased and the intervals between successive generations of improved systems. Moreover, the trend tends to be unstable. That is, the reduced quantities place a greater premium on assurance of higher quality, and the larger intervals between new starts require that the aircraft be designed for considerably longer lifetimes. The result is more stringent design requirements, leading not only to higher-cost products but also to more extensive development test programs to validate the designs. The longer development cycle also increases the risk of obsolescence prior to deployment, possibly necessitating critical equipment changes which increase development time even further.

As stressed in reference 7, a major factor influencing the increases is simply the demand for increased capability. Given that military aircraft must counter the threat of potential enemy systems (and, in fact, that commercial aircraft must similarly meet the threat of potential commercial competitors), each generation must be designed to provide increasingly greater capabilities. For the military systems, these needs have led to a progression of increasingly more demanding requirements for aircraft performance and maneuverability as well as for advanced weapon delivery systems and various forms of offensive and defensive avionics. They have also necessitated the incorporation of increasingly complex electronic systems for flight control and for integrated control of airframe, propulsion, weapon, navigation, and communication systems. Despite the continuing improvements in electronics technology and associated reductions in component size and weight, these increased capabilities have required the addition of several thousand pounds of electronic equipment, with apparently more still to come in the future. Expressed as percent of aircraft empty weight, the installed avionics weight aboard fighter/attack aircraft has quadrupled in the past three decades (reference 30).

The effective utilization of these complex systems in the more difficult environment of the higher-performance aircraft has created new demands on human performance and necessitated the addition of high-speed digital computers driving sophisticated information and display systems to enable the crew to exercise its management and control functions.

Along with the advent of the digital computer, there has been a tremendous increase in the effort and expense which must now be devoted to software development. In the presentation on avionics trends (reference 13), it was noted that the magnitude of the software task has increased by a factor of at least five in the last ten years, and that the cost of software development has risen to the point where it is now approximately equal to the hardware development cost.

Obviously, the increased complexity and sophistication of the new systems has created a serious reliability and maintainability challenge. The challenge is being met quite successfully — mean flight hours between failures have increased fourfold relative to the 1960's tactical aircraft. While this accomplishment has greatly improved operating effectiveness and economy and reduced life-cycle costs, however, it has added considerably to the development burden.

In short, technological progress has increased the threats and competition against which successive generations of air vehicles must be developed. As a result, new system requirements call for increasingly greater capabilities. The new designs must therefore incorporate more and more advanced technology and consequently the new developments are more complex and more costly.

It must not be assumed, however, that development time and cost increases of the magnitudes currently being experienced are totally unavoidable. To the contrary, opportunities clearly exist for program planning and management improvements which can effectively combat, and perhaps even reverse, the trends. Moreover, although most of the benefits of new technology are necessarily devoted to meeting the more demanding performance requirements, improvements in technology and in the application of technology can also be utilized to accomplish development savings.

As a prelude to discussion of possible avenues to development economy, several important characteristics of the increased time and cost trends should be noted:

- 1) Despite the large increases in development cost, the related problem of cost growth and overruns has actually diminished steadily during the 1960's—1980's period (reference 31). In terms of cost growth, the average overruns of fifty percent or more experienced during the 1960's reduced to less than half that amount during the 1970's and appear to be averaging considerably less than ten percent in the 1980's. The reductions in cost overruns have apparently resulted from improvements in cost estimation techniques, government pressures to generate and use more realistic estimates prior to full-scale development authorization, and more conservative contingency planning. While the improved cost prediction may not have resulted in cost reduction, it at least provides better definition of the cost problems to be faced in new programs.
- 2) Although total development time has approximately doubled, the interval between full-scale development go-ahead and first flight has remained essentially constant. The increases in overall time have occurred primarily in the decision period prior to actual go-ahead, and in the period between first flight and operational deployment.
- 3) Analysis of air vehicle system development cost trends (reference 32) has shown that, whereas technical problems and the impact of technical advances were dominant causes of cost and schedule growth in programs prior to 1970, the factors influencing growth subsequent to 1970 were predominantly management problems and program instability resulting from changes in budgets and requirements.
- 4) As explained in reference 29, many of the problems leading to increases in development time and cost affect collaborative multi-national programs even more seriously than they do the simpler one-party undertakings. It is quite possible that increases associated with this program form are inevitable and must be accepted as the price of obtaining the other important benefits of collaboration. Recognizing the consequences, however, it appears that exploitation of all possibilities for reduction of development time and cost should be given top-priority attention in the international programs.

Appreciation of these aspects of the problem is helpful in considering where to apply efforts directed at potential reductions in development time and cost. Because of the predominance of the non-technical facets, the programmatic improvement possibilities are discussed first, with initial focus on actions primarily under customer cognizance.

## POTENTIAL MANAGEMENT AND TECHNICAL REDUCTION OPPORTUNITIES

### "Front-End" Planning

The recent increases in development time, as noted earlier, have occurred largely in the early stages of the program during the military planning, political, and multi-agency or multi-national negotiations to agree on the need for a new program and to decide on its essential characteristics. (Admittedly, the decisions are more difficult now in view of the higher stakes.) It appears, however, that the longer planning period has seldom, if ever, been used adequately to accomplish the real planning required to establish a sound foundation for timely and economical development.

It was pointed out in several of the presentations, and repeatedly in the symposium discussions, that the initial program planning phases must be given greater attention and discipline to assure early optimal program definition. The conceptual and exploratory phases which precede the start of full-scale development consume only a very minor portion of a program's total cost — typically on the order of five percent at most. Nevertheless, decisions made during this stage determine irrevocably perhaps as much as eighty-five percent of the total life-cycle cost. Changes introduced beyond this point are unduly difficult, costly and time consuming. Obviously, firm requirements should be established as early as possible, and subsequent changes in requirements should be resisted strongly. To this end, thorough technical, performance, and cost tradeoffs must be accomplished and reviewed with the user agencies. The important roles of systems analysis and combat simulation in this process are reviewed in reference 16.

It would be naive to expect that national and international political interests could be excluded from the process. If requirements are imposed because of such influences, however, it is important that the cost, time, and performance impacts be determined and made clear to all concerned.

More thorough and detailed efforts in these early stages are also necessary to support meaningful cost estimation. Early, reliable cost estimates are essential to economical program planning, and the validity of cost estimation depends directly on the specificity with which the system can be defined.

The symposium discussions, citing the "Packard Commission" report (reference 33), also raised the point that additional emphasis during the early development stages can and should be placed on production and maintenance, so that the earliest design efforts can be directed at maximizing the benefits of computer-aided and computer-integrated design, manufacturing, and logistics.

The need for better front-end planning has been recognized by the military acquisition agencies. Unfortunately, the corrective measures taken have not necessarily resulted in obvious improvement. Reference 30 reports, for example, that the U.S. Department of Defense establishment of a high-level Defense System Acquisition Review Council (DSARC) as a mechanism to improve and streamline the process resulted in a situation in which a program manager is required to present numerous review briefings prior to meeting with the DSARC. Even granting that the reference 30 claim of an average 53 interim briefings may be overstated, it appears that considerable room still exists for effectively streamlining the front-end phases.

With respect to multi-national NATO programs, reference 29 and the relevant discussions suggested the possible value of a permanent "joint Air Staff", official or informal, to accomplish front-end studies prior to the negotiation of firm partnership agreements.

#### **Utilization of Proven Technology**

As stated earlier, a large factor in the increasing cost and time of air vehicle development has been the need for continuing technology advancement in order to improve performance capabilities to meet the constantly increasing military threat and commercial competition. Minor improvements would not justify initiation of a new program. Each new development, therefore, represents a step increase in level of technology.

The application and integration of major technology advances in a new design is a difficult and expensive undertaking. If, in addition, some of the technology must itself be developed or validated during system development, the burden becomes much greater. Obviously, delay or failure in a component or subsystem technology development affects the total program, and not simply the problem technology.

In several instances, the use of prototypes to validate and demonstrate the high-risk advances prior to full-scale development has successfully reduced the development cost and the time between full-scale development start and production deliveries. Although it need not approach the realism of a pre-production vehicle, the prototype to be effective must be considerably more than simply a proof-of-concept or research vehicle. It must be sufficiently representative of the actual innovative feature or features so that reliable estimates of cost and performance can be made, and the prototype test program must be sufficiently comprehensive for that purpose. In some instances, it may also be advisable to have the prototype usable for operational evaluation.

The nature of the most appropriate prototype will vary with the high-risk innovations being considered. In general, however, some form of demonstration/validation prototype will provide risk reduction and associated development economies in any program which includes the introduction of significantly advanced technology. An important additional benefit of the prototype project is its value as a model providing development and production lessons as well as technical risk reduction. The prototype program itself, however, takes time and costs money. It is too expensive to be developed as a "sales aid", and should be used only if the technical risk cannot be resolved adequately in ground testing.

Recognition of the importance of the demonstration/validation prototype is reflected in current undertakings such as EPA, Rafale, and the projected ATF prototype phase (references 14, 27, and 7). References 23 and 24 contain comprehensive discussions of the various prototype approaches and uses. Reference 23 also addresses the question of prototype use in competitive, multi-company, or multi-national programs, concluding that the demonstration/validation prototype approach is still desirable in these situations, but suggesting that this pre-development phase of the program be accomplished by only one or two of the contractors.

#### **Program Stability**

With requirements firmly established in the initial planning phase, with strict discipline enforced to resist downstream changes in requirements, and with advanced technology risk resolved in the validation prototype phase, it should be possible to plan an expeditious development program and to estimate its cost accurately. An ideal program plan, then, would be one in which schedule is optimized for development and production efficiency, and full funding is provided so that the schedule can be maintained. Although it is generally agreed that this approach would clearly result in large savings in both time and cost, government programs are more typically either planned with longer schedules in anticipation of annual budget limitations, or stretched out during development as the anticipated budget constraints actually materialize.

Reference 32 cites an example of the effects of stretchout on the F-15 production program, in which an efficient planned production rate was stretched out for three extra years. The result was a cost increase of over two billion dollars for the same number of aircraft — actually, a loss of more than 83 aircraft that could have been bought for the same total cost. The impact of arbitrary stretchout on a development program can be similarly harmful.

The concept of a stable program characterized by short schedule and full funding may be idealistic and incompatible with "real world" budgetary and political processes. In view of the consequences, however, it may well be the real world rather than the idealism that requires adjustment. Unfortunately, when budget constraints have threatened deferral of a major new start, the alternative of stretching out an ongoing development has usually been judged the lesser evil.

#### **Command Channels and Reporting**

It has been claimed that approximately twenty percent of the cost of a military development program is devoted to reporting, and that considerable savings could be realized by returning to the old "management by exception" mode in which cost, performance, and schedule "norms" were established and little formal reporting was required as long as the program remained on course. The latter approach to reporting, in fact, is still typical of many commercial developments.

One reason cited for the excessive reporting and slow decision-making in the military has been the cumbersome organizations, with numerous layers and dispersed expertise and responsibility. The argument is that the large staffs and compartmented responsibilities have been necessary to compensate for the relative inexperience of military program managers who typically rotate into acquisition assignments with little or no acquisition background. As new starts become even less frequent, this problem could well be aggravated. Organizational tightening clearly appears necessary.

There is evidence that the apparent overstaffing exists in the contractor as well as the customer organizations. One interesting statistic quoted during the discussions was that the "non-touch" percentage of a contractor's labor force has increased from twenty-five percent in the 1950's to seventy-five percent in the 1980's. Although much of the "non-touch" labor is devoted to necessary planning, software, and support functions, it appears that an appreciable portion of the staffing increase is related to customer-imposed reporting requirements, and that significant opportunity exists for savings in this area.

#### **Requirements**

The adverse impacts of requirements changes during development have already been discussed. Some additional concerns relative to requirements should also be noted. The charge is frequently made that customer specifications include some requirements which are unduly demanding, and some which are wholly unnecessary. Despite customer denials, these claims represent a strong industry consensus — and with requests for proposals typically containing over a thousand pages and apparently growing (reference 30), the denials are not entirely convincing.

It has also been shown (e.g., in reference 8) that meeting a demanding performance requirement to the hundred percent level may add inordinately to the cost compared, for example, to ninety-five percent compliance. If the additional five percent represents an absolutely essential margin of military superiority, the higher cost may be unavoidable. In some instances, however, a requirement is treated as sacrosanct because of insistence by one specialist group in the customer organization, when trade-offs might show that minor relaxation can permit development (and perhaps life-cycle) savings far more significant than the associated performance compromise. Thus, beyond the obvious observation that development specifications should not include unnecessarily severe requirements, flexibility should be retained to review a requirement for possible relaxation when unanticipated technical difficulties threaten excessive development delay or cost growth.

#### **Planned Product Improvement**

The Planned Product Improvement (PPI) concept has been advanced as a means of reducing development time and cost for new air vehicle systems. In a sense, it is more accurately a means of avoiding new air vehicle system developments. Simply stated, the concept is to develop interchangeable subsystems (e.g. new avionics, new engine, new weapon system, perhaps even new airframe) which can be substituted into a system at appropriate points in the production cycle, rather than packaged simultaneously in a totally new system development. As explained in reference 2, the concept is also coupled with the proposition that off-the-shelf commercial electronic components and subsystems can be used instead of specialized military equipment at great savings in cost and time.

It remains to be seen whether the PPI concept in its entirety will be found practicable. In the meantime, however, it is possible that the idea can be exploited in part with respect to selected components to accomplish time and cost savings in new developments.

#### **Combined Testing**

Consolidated flight testing is already being accomplished and is expected to result in appreciable time and cost savings in development programs now in progress. The concept as practiced by the U.S. Air Force is outlined in reference 21 and discussed in greater detail in reference 34. It replaces the independent, sequential testing conducted by the contractor, the customer development test center, and the user operational and support test agencies with coordinated test programs conducted concurrently at a single test location by both contractor and government personnel.



The combined test force offers advantages and savings through commonality in instrumentation, test planning, range facilities, maintenance and support, data bases, and aircraft. It also eliminates duplication and provides for earlier user involvement and identification of potential operational problems prior to volume production.

Air Force experience thus far indicates that the benefits far outweigh the additional expense incurred in relocating test teams and equipment, and the occasional inconvenience associated with shared utilization of facilities and equipment. With respect to multi-national programs, agreement on the location of a "world class" common test site (which represents considerable capital investment) may complicate application of the combined test concept. If the savings are adjudged sufficiently great, however, the question should be resolvable.

#### **Contractor Program Management**

The burden of reducing development time and cost cannot of course be laid upon the customer alone. The contractor may have no control over the establishment and maintenance of requirements, or the budgetary stability, or other influences on the program structure. As the implementing agent, however, he carries the responsibility for conducting and managing the program as efficiently as possible within the constraints he has contracted to accept — and some of his opportunities to effect savings are quite similar to those open to the customer. As pointed out in reference 25, for example, the contractor too must avoid overspecifying with respect to subsystems and components, or making avoidable changes after his own front-end planning activity.

The contractor can also benefit from assigning a team characterized by high qualifications, experience, and motivation rather than quantity. In this connection, reference 26 illustrated that the more popularly publicized approaches to productivity improvement are not directly applicable to the professional work force which is increasingly critical to high-technology development, and that the aircraft industry can still profit by further improvements in "white collar" productivity.

Reference 7 stresses the importance of avoiding errors, duplication, and schedule inconsistencies which can lead to rework, delay, and cost increases. It outlines a computer-driven integrated project management system, employing a U.K.-developed software package, which increases the ability to manage complex interrelated activities. Together with a disciplined risk closure process and a new joint engineering/manufacturing/quality integrated product definition approach, the improved project management system is expected to achieve appreciable reductions in new combat aircraft development effort and time. Similar points were made in reference 28 with respect to helicopter development, and it is apparent that contractors are constantly striving to improve their program management processes.

Several of the papers also reported improvements in — and additional applications for — parametric cost estimation techniques, reference 4 recommending specific application to development cost, reference 5 to the selection of "winners" from a range of competing alternatives, and reference 6 to equipment modernization rather than new aircraft system development. Although there is no basis for concluding that new parametric cost estimation approaches offer promise of major reductions in development time and cost, it seems clear that good cost estimation based on the best available methods and data must be made as early in the development as possible, and updated as better information emerges.

#### **Computer Integrated Manufacture**

Although in use for more than a decade, Computer Aided Design (CAD) and Computer Aided Manufacture (CAM) have achieved only limited productivity gains and have not resulted in major reductions in development time and cost. The explanation given in reference 20 is that the use of CAD/CAM technology has been localized and not balanced throughout the company. The hope expressed is that the overlay of Computer Integrated Manufacture (CIM) will bridge the gaps between the "islands of automation" and create a balance in which the benefits are realized in all areas and, more importantly, in the operation as a whole.

The technology required to accomplish the integration consists of high-speed computer networks to collect, check, store, handle, transmit, and where necessary reformat data (including three-dimensional geometric model representations) for use by all departments of the company from conceptual design through final assembly. Elimination of the manual efforts otherwise required for these purposes is expected to reduce errors and produce very large time reductions, with target savings as much as forty percent quoted.

Much of the necessary CIM hardware and software capability already exists, and elements such as "paperless systems" and "electronic mock-ups" are already in use (references 7,11,20, 24). Implementation of the fully integrated system concept, however, may still require several years of additional investment and development.

#### **Simulation**

Man-in-the-loop simulation has been used as a fixed-wing aircraft development tool for many years. Recent simulation contributions, to Airbus development and to the EAP prototype, are discussed in references 17 and 14. Application to rotary-wing aircraft has been limited because of difficulties associated with low-altitude visual and sensory fidelity and the greater computational sophistication required for representation of the more complex aeromechanical phenomena. As discussed in reference 15, simulation technology advances over the past five years have largely overcome these difficulties and full-mission engineering simulator use appears capable of effecting development and flight test savings amounting to more than a year and

several millions of dollars. These savings are particularly important because the interval between first flight and certification for rotary-wing aircraft has been three to four times greater than for fixed-wing aircraft (reference 8).

The relatively new importance of simulation, as brought out in references 21 and 22, is in support of development flight testing. In this application, simulation provides early flying qualities familiarization, identification of risk areas and problems for flight concentration, pilot training for specific tests, opportunity for multi-pilot participation, greater control of experiments, and simple repetition of test conditions -- all contributing to time and cost savings as well as improved test results. For avionics test support, simulation can be particularly valuable in that it permits resolution of seventy-five percent or more of software problems at a fraction of flight-test cost and considerably less time. Reference 21 indicates that, in a typical fighter development program, effective use of ground-based avionics simulation can eliminate twenty aircraft-months of flight testing for total cost savings close to thirty-four million dollars.

#### Test Data Systems

The acquisition, communication, and analysis of flight test data has improved dramatically in the past two decades. Advances in computational capability and display technology have greatly accelerated the pace and productivity of flight testing (and of wind-tunnel and other ground-based testing), and has made possible virtually instantaneous analysis of test results and comparison with design predictions. These benefits should be translatable to improved efficiency and substantial development savings, but appear instead to have invited large increases in testing and data requirements. Some of the increases may be necessary, either because of the greater complexity of the new systems or because the testing was inadequate in the past, but there remains a suspicion that both customer and contractor may in some instances be fostering unwarranted proliferation without critically assessing the needs or the lost opportunity for additional time and cost savings.

#### CONCLUSIONS AND RECOMMENDATIONS

The symposium presentations and discussions reconfirmed that the large and apparently continuing increases in air vehicle development time and cost will, unless checked, seriously impair our ability to afford the new weapon systems that will be needed in the future.

A major cause of the increases has been the continuing escalation of military threat technology, creating the necessity for increasingly advanced technology in our own combat aircraft developments. Although this aspect of the increase may be unavoidable, it has been exacerbated by a number of deficiencies in the development process which can and must be alleviated:

- The initial decision phase, in which the necessary top management and political agreements on the program are reached, has become absurdly long.
- The front-end planning, despite the leisurely pace and despite the fact that it indelibly dictates the program cost, has usually not been utilized adequately for early establishment of firm, rational requirements based on thorough tradeoff studies.
- More restraint is needed to discourage unnecessarily severe requirements and changes in requirements once they are established, particularly when the program is well under way.
- At the same time, more flexibility is needed to relax a requirement when unanticipated technical difficulties impede full compliance and relaxation would not seriously degrade system effectiveness.
- Program disruptions due to political or budgetary instability have made it difficult or impossible to set and adhere to optimal development schedules, and have added considerably to the cost.
- Development inefficiencies resulting from the high risk associated with unproven technology can be avoided through the timely and productive use of demonstration/validation prototypes.
- Opportunities for improvement in program management exist in both the customer and the contractor operations -- e.g., by eliminating excessive layering and decision levels, reducing staff size, increasing experience level, eliminating unnecessary reporting requirements, improving project management integration, and implementing productive automation throughout the system.
- Although it has been necessary to utilize technical advances almost exclusively to achieve greater required capability rather than development economy, some technologies (simulation, advanced data processing and display systems, computerized project integration) still offer opportunities for development time and cost reduction -- provided the benefits are not negated by increased requirements for non-essential data and testing.

The needed corrective actions are obviously well beyond the purview of the Flight Mechanics Panel. However, several recommendations can be made regarding constructive steps that might be taken by the Panel:

- (1) Pursue all possible AGARD avenues for promoting meaningful consideration of the development time and cost reduction issues at national and international acquisition "summit" levels.

- (2) Consider expanding ongoing Subcommittee or Working Group activity to address specifically the question of simulator capabilities and usage for maximum contribution to development economy.
- (3) Consider a similar review of development flight testing to determine whether substantial reductions in test or data quantities might be possible without serious compromise to essential results.

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2. Keynote address — *Dr. J. Gansler, U.S.*
3. Risk Reduction — Cost Avoidance for Full Scale Development Begins with Concept Formulation. C. Crawford, Jr., U.S. Army AVSCOM, U.S.
4. Development Savings Through Parametric Modelling of Program Costs. P. Leslie & E. Lilley, Bell Helicopter Textron Inc., U.S.
5. Picking Winners: Parametric Cost Estimating and Project Management. P. G. Pugh, Ministry of Defence, U.K.
6. (A Parametric Study of Total Cost of Aircraft Modernization Versus Cost of Equipment Development and Production Costs.) J. P. Bayle, STPA, France.
7. The Increased Time and Cost Of Development: Causes and (Some) Remedies. J. T. Gallagher, Northrop Corp., U.S.
8. Reasons for Increasing Development Cost of Rotary Wing Aircraft and Ideas to Reverse the Trend. V. Von Tein, Messerschmitt-Bölkow-Blohm GmbH, Germany
9. The Judgement and Evaluation of Long-Term Investments Demonstrated by Means of a Civil Aircraft Programme. W. Zabka, Messerschmitt-Bölkow-Blohm GmbH, Germany
10. (How to Face Growing Development Costs.) C. Henocque, SNECMA, France
11. Development Cost Reduction Using Integrated CAE/CAD/CAM Techniques. D. Falco, Aeritalia, Italy
12. Optimizing Powerplant Design and Development Cycles. L. Bevilacqua, General Electric, U.S.
13. Avionics Acquisition Trends and Future Approaches. R. Longbrake, U.S. Air Force, U.S.
14. Reducing Time Required for the Development of Avionic Systems. W. R. Scarte & K. Grantham, British Aerospace, U.K.
15. Reducing Rotary Wing Aircraft Development Time and Cost Through the Use of Simulation. S. Ranaachandran, W. Richeson, & D. Borgman, McDonnell Douglas Helicopter Co., U.S.
16. Systems Analysis and Simulation Techniques — Essential Tools for Balanced Complex Weapon System Designs in Terms of Performance and Cost. K. Fetzelschoss, Dornier GmbH, Germany
17. (The Contribution of Simulation in Airbus Development.) M. Pedestarrès, Aerospatiale, France
18. Prototype Manufacturing Techniques for Reducing Cost, Schedule, and Technical Risk. J. Williams & M. Schuessler, Boeing Military Aircraft Co., U.S.
19. Structural Materials — The Changing Scene. R. Haresceugh, British Aerospace, U.K.
20. Time and Cost Reductions Through Computer Integrated Manufacture. J. B. Cox, British Aerospace, U.K.
21. Minimizing Development Flight Time and Cost in the U.S. Air Force. C. E. Adolph, U.S. Air Force, U.S.
22. Improved Flight Test Productivity Using On-Line Data Systems. P. Dunford, Boeing Vertol, U.S.
23. Use of Demonstration/Validation Prototypes : Impact on Total Development Costs and Times. A. Notari, Aermacchi S.p.A., Italy
24. Prototype Development Acceleration and Cost Savings Due to Multi-Disciplinary Integration.) J.-Y. Lazard, Avions Marcel Dassault-Breguet Aviation, France
25. Engineering Management for Validation Prototype Phase. A. Neviani, Aermacchi S.p.A., Italy

26. Schedule and Cost Control of Development. K-H. Engleitner, Messerschmitt-Bolkow-Blohm GmbH, Germany
27. People, Procedures, Performance — The Keys to Improving the Development Environment. C. D. Scales, Theodore Barry & Associates, U.S.
28. (Organizing Helicopter Development Activities in View of Reducing Cost and Cycle.) A. Desmonceaux, Aerospatiale, France
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14. Abstract			
<p>There is a current perception that time and especially the cost of the new <sup>9. Tactical aircraft</sup> systems are increasing at an ever accelerating rate that is greater than the rate of improvement of the capabilities of the machines. The purpose of this symposium was to provide a forum to identify and discuss the elements that contribute to the increased time and cost development, and to explore the question of what can be done to arrest and reverse the trend.</p> <p>Another aim of this symposium was to encourage others in the nontechnical area to join with the technical people in attacking these problems resolutely. <del>It is considered that</del> the meeting was successful in focusing attention on this situation, showing what technologies can do to reduce development time and cost growth, and by highlighting key areas that must be addressed to reverse the trend. The final recommendation of the symposium was to make sure that military and government leaders get this message.</p> <p>The Conference Proceedings, <del>commissioned by the AGARD Flight Mechanics Panel,</del> are published separately as AGARD CP424, <del>ADA-198663.</del> <sup>Keywords:</sup></p> <p>This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.</p>			

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